White Paper
Spaced practice

This paper shows how organisations and learners can optimise their learning and performance, through spaced practice, based on the science of learning. It covers motivational and metacognition issues, as well as practical methods for spaced practice.

These methods include formal and informal methods for the consolidation of learning.

Donald Clark

learningpool

Please Share Me

Table of Contents


Mathew Syed

Why spaced-practice?

This is Mathew Syed, Britain's No. 1 table-tennis player for ten years. Not only that, the next five best players all lived within a few streets of him. How come? Well, they had a great coach, a club that was open 24 hours a day (they all had the keys) and a group who practised, deliberately and mercilessly to get to the top. It was nothing to do with natural 'talent' and everything to do with effort. It's all in his excellent book 'Bounce' (Syed 2011) where he explains not only his sporting journey but the psychology behind that journey, in particular his discovery of deliberate practice. Practice may make perfect but that is not the whole story. It is not simply a matter of repetition or following a pre-determined pattern of exposure. Spaced-practice is much more than this. At its simplest it is the recall, rehearsal, revision, application or deliberate practice and recall of knowledge of skills spaced over time to reinforce and consolidate them in long-term memory for quick recall. Ultimately it's about performance, using evidence-based learning theory to apply the most effective techniques that lead to measurable performance.

Spaced-practice in practice

Experienced learners know that spaced practice; the repeated active recall, revision and application of knowledge and skills really does matter. Good learners do their homework, develop revision techniques, repeat and rehearse in their heads, take notes and so on. This is often without any real guidance from the educational system, but they eventually realise that it is what leads to success.

So, given that millions of teachers, lecturers, trainers, coaches and instructors are employed in the learning game, it is perhaps surprising that little or no attention has been paid to the idea of spaced-practice. One could argue that without knowledge of this principle and its causes, those who teach are missing a key component in the process of learning.

This a little unfair, since most traditional learning has been in fixed courses in training rooms, classrooms or lecture halls and once the student has walked out the door, they have gone. All attempts at practice, revision and application are down to them. That shouldn't distract us, however, from making the effort to improve the situation, with or without technology.


Ebbinghaus

What is spaced-practice - Ebbinghaus?

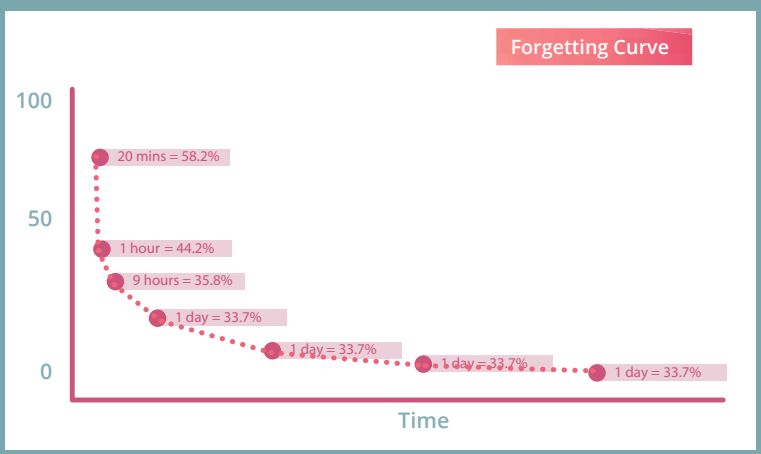
Ebbinghaus, in 1885, published Über das Gedächtnis (On Memory), published in English in 1913 (Ebbinghaus 1913), a groundbreaking work, which laid the foundations for the practical science of memory. Not only did he give us the application of the scientific method to the measurement of memory, this also resulted in some startling findings.

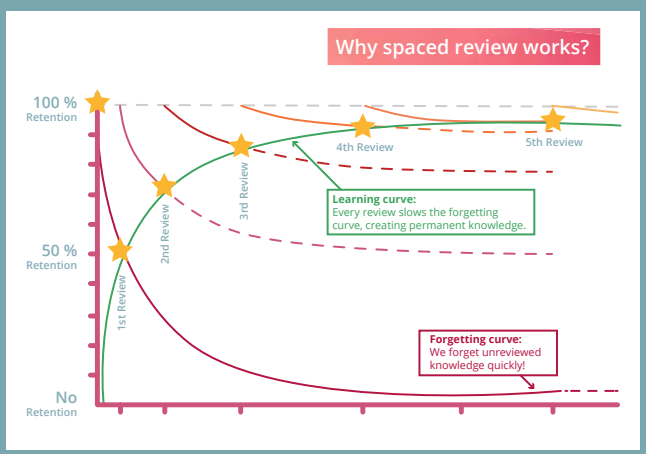
First, the famous forgetting curve, that even now, has the ability to startle those who first encounter the precipitous nature of forgetting. He also explored chunking, an essential principle in memory and learning theory, a practical response to the severe limitations of working memory. Then there are his findings on primacy and recency, showing that we have a tendency to remember the first and last things in a learning experience.

Forgetting curve

Let's focus on the forgetting curve. This applied to the recall of short strings of letters, and not all of the evidence for forgetting is as pronounced as this. Nevertheless, it is certain that most learning experiences lead to some, and usually substantial, forgetting. Although decay rates are variable this should not detract us from the task at hand, which is to increase the productivity of learning through increased retention and recall from long-term memory.

A solution to the problem of the failure to elaborate and shunt learnt knowledge and skills from working memory to long-term memory is to repeat, review, revise, rehearse, recall and practice at spaced intervals in the future. Evidence suggests that the periodicity of these intervals matters but it is also important that it involves active recall and not just the recognition of answers. Whatever profile the forgetting curve has, and almost all learning results in a quantifiable fall, the cure is clearly to do more to consolidate the cognitive gain beyond that initial experience. If most of what we learn is forgotten it should be an imperative to slow the forgetting curve. The science suggests that this one technique has the greatest chance of substantially increasing productivity and performance in learning.





Science of spaced-practice

Memory theory is one of the most developed areas of experimental psychology and learning theory, yet the learning industry, schools, further education, higher education, corporate and adult learning have taken little practical advantage from these theoretical advances. So what does the science tell us?

Learning, memory and performance

All 'learning' comes down to encoding into memory with performance being the retrieval of that stored knowledge and skills (Anderson 1994). Yet, much learning has been shown to play to short-term memory with rapid and on-going decay. This cramming or sheep-dip learning plays to short-term memory and recall, and does not have high retention value (Dempster 1988).

Encoding matters, so chunking of the original material to prevent cognitive overload, along with media techniques to grab and sustain attention really do matter. But to consolidate memories, repeated active practice pushes knowledge and skills from working to long-term memory then consolidates these memories to make them more permanent. Spaced events, combined with repeated retrieval, consolidate memories and improve accurate recall. In practice, the repeated spaced-practice intervals get longer over time.

We have known for over a century that memories decay over time. We also know that memory is better encoded the more times it is actively learnt and that the same amount of active learning is better if distributed over time. This is important as spaced-practice gives you better performance with optimal effort. Additionally, memory is a process of reconstruction and the more we recall a learnt item, the more recallable it becomes in the future (Bjork 1988).

Cues and consolidation

Memories are encoded (Anderson 1994) into long-term memory and can be consolidated (made stronger) by repeated, active spaced-practice. Spaced-practice also increases the probability, speed and performance. The promise is that the learner will be more likely to recall something quicker and better. This is why the retrieval through spaced-practice is so important. It prevents memory loss (Bjork 1975). The more we recall, the more recallable memories become. But the efficiency of recall can be made all the stronger by the use of 'cues', namely stimuli that help you recall knowledge and skills.

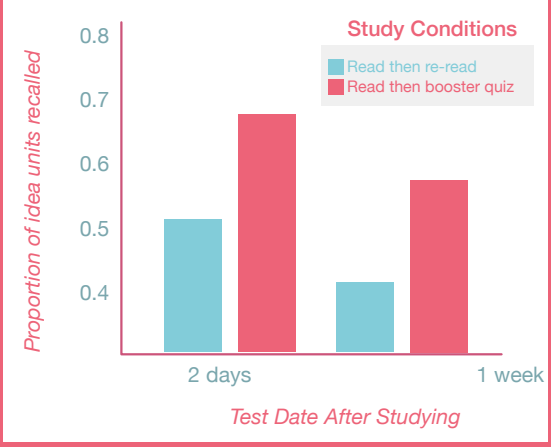
Cues are important, as it is cues that activate the memories for recall. They're like the handles on suitcases, which you can use to haul out stored memories. Cues can be mnemonics, contextual, and there is evidence (from Kuiper & Kirker - 1977) to suppose that they are strong when self-referenced i.e. the learner creates their own cues when encoding things to be remembered. Memory systems used by high performing memory champions use 'memory palace' techniques that are remarkably efficient in aiding cued recall. Typically you would place the items to be remembered along a well-known street you know or in the rooms of your own house, then use that known place as a cue-rich

environment you are already familiar with, to recall new knowledge. If courses are chunked, and cues deliberately provided, so that each chunk has cues or encourages the learner to create their own cues, this is useful in the construction of spaced-practice, as it is the cues and not just bits of content that can be spaced and used for recall. Later practice events can be contextual cues, where a contextualised scenario is presented.

Active recall

Active recall, pulling something out of memory, not just recognising something from a list or multiple choice question, improves future performance, something we have known for a century (Gates 1917). The act of active recall develops and strengthens memory. It also improves the process of recall in ways that passive recall – reading, listening and watching - do not. In practice, it is active recall that really matters in knowledge and skills, not recognition. An additional advantage is that if we learn in a way that mimics the conditions of future recall (rarely just recognition), recall is all the more certain (Morris et al 1977).

Let's get more precise on active recall. Professor Roediger at Washington University in St. Louis has researched this in detail. In this study students had to memorise pictures. Group 1 were simply asked to remember as many as they could, Group 2 were given a booster quiz where they were asked to actively recall as many pictures as they could, Group 3 were given spaced-practice recall exercises. No extra study was provided in any of these exercises. In a test a week later there were clear differences in performance. A weakness of this experiment is the charge that there was still more 'learning time' through the recall tests, so Roediger split students into two goups. Group 1 read a science essay and were allowed to reread that essay. Group 2 did the same but rather than re-read they were asked booster recall questions. A recall test 2 days later showed a clear difference and that difference was even more marked after 1 week in Group 2. We can take advantage in a formal, pushed system to push out cues and active recall, on knowledge that users have shown they don't know, don't know well or don't feel confident about. Active recall and/or practice generally produces much greater performance benefits, especially repeated and spaced testing. These have been shown in many trials to be superior to the re-presentation of content. Allen, Mahler, & Estes (1969), Hogan & Kintsch (1971) Nungester & Duchastel (1982) Cuddy & Jacoby (1982) Kuo & Hirshman Izawa (1992). When this active practice is accompanied by feedback, it has even greater benefits.



Levels of learning

Attention matters as it is a necessary condition for learning, but vigilance (sustained attention) is just as important. The problem with much traditional learning is the unrealistic and unsustainable attentional expectations; one hour lectures and long bouts of e-learning are good examples, where attention has been shown to drop dramatically.

Attention can be held by good design, variation, relevance and personalisation and is a necessary, not sufficient, condition for learning. We can distinguish between four levels of learning:

1. Familiar – knew but can't now remember
2. Recognised – correctly recognise answer in a multiple choice question
3. Recalled – recall with effort but without help
4. Automatic – immediate, effortless, high-performance recall

It is quick and 'Automatic' recall that is the goal of high-performance learning and expert ability. So, even after good recall is achieved, it can be improved through practice, this is why it is important in spaced-practice to include known items. Note that when Automaticity is achieved, it is almost effortless and therefore doesn't demand massive cognitive effort, freeing up cognitive capacity for other tasks (Carnine 1989).

Forgetting

Although students often perform better immediately after 'massed practice' (single bout of practice), they forget quicker and perform poorly in later tests than 'spaced-practice' students (Keppel 1964). This is why much end-point assessment is short-term and short-sighted.

Forgetting is initially steep and shows that memories are lost very quickly then more slowly, so forgetting is not simply proportional to the passing of time (Wickelgren 1976).

One solution to this predictable process of forgetting is spaced-practice which works, as Ebbinghaus discovered, through the spacing effect; the separation of learning events over time (Dempster 1988). As forgetting is a curved descent, so methods that combat forgetting (remembering) need to be spaced across a curved ascent.

But it is the combination of spaced-practice with active recall (Landauer and Bjork (1978), with repeated sessions, as well as greater gaps, that leads to optimal retention and recall.

The timing of this practice is important. We know that there is a point, soon after the learning experience, where it is essential to practice but as decay slows over time, the practice sessions can be increasingly spaced out over time. This typically follows a minutes, hours, days, weeks, months pattern.

Agency

All of the above encourage student agency, where the learner plays a role in determining what they need to practice more. Agency, as a feature of memory, is important in terms of improving performance. This self-awareness of one's own learning and processes, such as memory, is called 'metacognition'. This metacognition (Tulving & Madigan 1970) can be used to control and improve learning (Nelson & Narens 1990). We also know that, if learners' metacognition skills are low, they often fail to plan their study so that optimal learning and retention takes place (Nelson & Leonesio 1988). This can work to the student's disadvantage. Zechmeister and Shaughnessy (1980) showed that metacognition of massed repetitions give learners a false view of their ability to recall knowledge.

An additional feature of spaced-practice is the self-awareness of the learner in relation to their confidence that they know something. However, simplistic metacognition, the students' knowledge of their own learning is a double-edged sword. Self-perception of ability can both help and hinder learning. The bottom line is that one can study too little or too much (Nelson and Leonesio 1988). This has led to spaced-practice systems that allow the learner to express a rating on their feeling of confidence about their ability. Spaced-practice can therefore be selective in that items that are clearly known can have less weight than items which the user is not confident about, had difficulty in learning or clearly doesn't know. Here spaced-practice can involve algorithmic inferences that use performance data about each individual learner, then route that learner through a series of items, or network of knowledge, based on optimising their learning and spaced-practice.

It should also be noted that the use of spaced-practice methods improves a learners metacognitive skills and makes them better learners. Applying a formal method can lead to more informal methods and habits being adopted.

Habitual spaced-practice:

Blended learning

To give spaced-practice a real, practical, performance context, lets consider its place in blended learning. Blended learning has become an acceptable shorthand for learning experiences that are sophisticated in that they are deigned around the real needs of the learners, types of learning and resources you have at your disposal, along with costs. Note that blended learning is not blended teaching, where you simply slam together a bit of offline and online (sometimes known as Velcro learning). It is about optimising the learning experience for the learner. Every blended learning experience should at least consider spaced-practice as a way of maximising learning outcomes and there are many ways to introduce spaced-practice into a blended experience.

Blended components can include a wide range of spaced-practice opportunities; simple repetitions, repetitions with concise cued phrases, stories, graphics, examples, analogies, metaphors. More active retrieval components include; tests, practice, exercises, simulations, case studies and role plays. Deeper retention may also involve; discussion, debate, dialogue and collaboration.

Habitual spaced-practice

Spaced-practice needs to be habitual. These habits are common in experienced and successful learners but take time to learn and in themselves require repeated practice to become habitual.

John Locke and William James both emphasised the key role that 'habit' plays in learning; lessons we've largely ignored. Good learners develop good learning habits. They always have something to read in their pocket or bag. They tend to be obsessive note takers, often with a long series of filled notebooks. They habitually elaborate what they hear and actively try to remember. They replay and recall in their own minds, through dialogue and re-reading their notes. They also tend to kick-start new learning habits using technology, such as bookmarking and blogging.

So how can we make spaced-practice habitual? We also have to be conscious of context and the affective, emotional and motivational side of learning. It's also about habits – sleep, time, place, having a notebook, note taking, email, social media, blogging, mobiles, wearables and so on.

Spaced-practice is on the agenda not only because it works but because we now have the tools and technology to make it work. To limit the concept of spaced practice to repetition is to limit the principle and limit our imagination when it comes to solutions. As we will see, with technology we have a chance to create learning habits in ways that were never possible even a few years ago.

Informal spaced-practice:

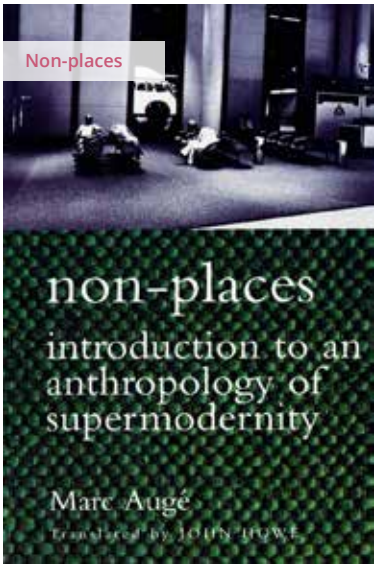
Top and tail

One of the simplest techniques is to top and tail identified course chunks. This could be lectures, classes, periods, breaks or modules. Take a lecture. Before you start, summarise succinctly what was taught in the last lecture, then summarise at the end of the lecture. This inserts a small dose of spaced-practice, preferably an active learning experience, to the learner, with practice being presented, three times – once during the lecture, once at the end and once again at the start of the next.

There is a double dividend here, as this also plays to the known principle of primacy and recency (we remember the first and last things more than the things in between), taking advantage of a cognitive bias to consolidate learning. The same can be applied to classroom training, with summaries before and after coffee breaks. Similar techniques can be used in e-learning, where modules are topped and tailed. In other words, take advantage of every break, section, module to include a summary which repeats or gives an opportunity for learners to recall, what was learnt. Across a term you can use regular quizzes, where 50% is new and 50% is old material. These overlapping tests are, in practice, spaced-practice.

Notes

As a learner, get into the habit, not only of taking notes, but rereading and rewriting those notes. When reading books, underline key points. At the end of each chapter, write a small summary. Even better write a review of the book. Marx used to write a summary of every book he read. Studies on note taking (with control groups and reversal of note takers and non note takers to eliminate differences) show overwhelmingly that note taking increases memory/retention. Many aspects of increased memory have been studied including; increased attention, immediate recall, delayed tests, free recall, MCQs, remembering important v less important knowledge, correlations with quality of notes and deeper learning. Bligh (2000) has detailed dozens of studies in this area. Wittrick and Alesandrini (1990) found that written notes increased learning by 30% through summaries and 22% using written analogies, compared to the control group. Why does note taking increase retention? First, increased focus, attention and concentration, the necessary conditions for learning. Second, increased attention to meaning and therefore better encoding. Thirdly, rehearsal and repetition, which processes it into long term memory. All three matter.



Places

Marc Auge wrote a book called 'Non-places' which are those many places where we increasingly spend our time – trains, planes, hotels, railway stations, airports and so on. These places have become havens for isolation, reading and, habitual spaced-practice. We could add to these the places we regularly inhabit day-by-day, like the kitchen, the toilet and so on. One trick I've heard used in language learning, is to put up vocabulary lists, grammatical rules etc., on the back of the toilet door, even on objects around the house. A couple of minutes every day, while you go through your ablutions may just prevent the natural excretion of that knowledge you worked so hard to remember. This is about developing the habit of learning through reinforcement so look for that unproductive downtime.

Sleep

One of the most effective methods of habitually delivering spaced-practice is to encourage learners to get into the habit of a little recall just before they go to sleep. This takes discipline but studies show that it is very effective as the brain appears to consolidate memory during sleep. We now know that a lack of, or interrupted sleep, is detrimental to memory formation. A full night's sleep helps as the first couple of hours consolidates memory in the hippocampus, the next few hours moves memories to the cortex for long-term storage and the final few hours results in cortex rehearsal.

A magazine (www.scientificamerican.com) published a paper in which learning was tested comparing those who learn then 'sleep on it' overnight, compared to normal '9-5' daytime learners. They forced subjects in two groups to learn a new set of word pairs 12 minutes prior to testing-the well-rested radically outperformed those who had not slept; 76% of sleepers accurately recalled the initial pair compared to just 32% of their peers who had gone without sleep. "Memories after sleep are resilient to disruption," the researchers conclude.

Technology and spaced-practice

Formal, automated and semi-automated spaced-practice usually (not exclusively) requires technology and approaches that deliver spaced events to the learner. It is often push rather than pull. There are many ways to use technology to push and manage spaced-practice, from the simple to complex. In all cases pedagogy is the driver, technology the accelerator.

Email

Many learners use email so this is an easy and efficient and familiar way to deliver spaced -practice events. Group emails, set up and timed for release, can get spaced events straight to the audience. A simple text email, infographic, question, video, even piece of e-learning; anything that makes learners rethink and recall, will help consolidate and fix the learning in long-term memory. One can even ask for a reply to encourage active learning and ensure that it has been opened. For larger audiences there are tools that manage the delivery of large batches of emails.

Twitter

The psychology of learning constantly reminds us that less is more, and in a world that is plagued by cognitive overload, the massive popularity of Twitter, which is short and sweet, is proof that this rule is well received. Indeed, Twitter has become a common, if not intentional, form of spaced-practice. When we Tweet something that catches our eye we reinforce that point in our own minds. Good Tweets also act as good cues for the retrieval of content, as can retweets. With this in mind they can be re-used for spaced-practice. Twitter streams are sometimes collated after a talk or conference, again a form of spaced-practice for participants. It has, of course been boosted by the use of mobile devices.

Facebook

Given the fact that 1.5 billion people are on Facebook there's a good chance that learners are easier to reach on Facebook than they are in the institution, LMS, VLE or any other physical or virtual space. The notifications system on Facebook is superbly efficient and that little red circle with a number in it is a strong stimulus for attention. Simply message students with a series of cues and reinforcement events from the lecture or course.

Blogs

Blogging is, in this sense, a massively effective way to reinforce learning. It's one of those practices that, when it becomes habitual, is massively effective as an aide memoire. Many bloggers claim that the act of writing up blog posts forces them to summarise and articulate their learning. It also gives them an archive of content for future refreshment. There are many in education and training that now recommend blogging in the context of learning. One can start with teacher/trainer blogs around what you taught this week. This gives students a second bite of the content, as well as expanding out content with media and links. Learner blogs based on what the learner did learn that week can also be useful as the exercise forces them to reflect and summarise their learning experiences, playing on the fact that note taking (writing) increases retention.

Podcasts

If you exercise regularly, that is a chance to regularly recall and reinforce whatever you want to retain. A podcast through your headphones can be listened to while running or exercising. Similarly in the car. Simply record your own lists, notes, reinforcement events and replay on demand. Get into the habit and you'll get both physical and psychological gains.

Games

Games use a learning technique that is built into their design – spaced, repeated practice. Within many computer games, the player will die or fail and be pushed back to the start of the level or the place from which they started. This catastrophic failure makes games players focus their attention on not dying or failing, accelerating their rate of learning. This remedial loop on failure is a classic game feature and we have much to learn from it in learning design, as it builds in the reinforcement of learning into the entire learning experience.

Advanced technology and spaced-practice:

Encore

Spaced-practice software tools, such as ENCORE, uses mobile devices to deliver cued spaced-practice for learning. Tools like this are a major breakthrough in learning technology. For mobiles the advantages are around quick, episodic events such as texting, photographs, looking things up, quick experiences, games or alerts.

The average time someone spends on a mobile device is seconds, and it's getting shorter as texting on WhatsApp or whatever, overtakes voice. As we use mobiles for short, episodic experiences, it follows that they can be used for short bouts of spaced-practice.

Learning is one of the most unproductive areas of human endeavour. The trick is to look beyond the course and learning experience to the reinforcement of that knowledge and skills. This has never really been possible in learning, as we lose the students attention as soon as they walk out of the door. Suddenly a miracle has happened, we all have the ideal device – mobile phones. These powerful, personal and portable devices can deliver personalised learning at anytime, anywhere to individual learners.

ENCORE, takes the 'cues' from any course or learning experience and spaces them out in whatever frequency you determine after the course to an end-date. It may be spaced out up to the start of a new job, an exam, a product launch, whatever.

As mobile systems develop, significant increases in retention and productivity could be realised. We can remind learners about tasks, activities and push snippets of learning topics to them at timed intervals. Systems like this can insert new life into previous learning with bite-size questions, tasks and activities to help refresh the learners' mind.

One problem with formal, pushed methods is habituation. This is seen in pop-up help or tip systems, where the user tires at being interrupted and starts to ignore the events that are pushed to them. This motivational problem can be solved by not being too aggressive with the push techniques, keeping them short, varying them and making them worthy of attention.

Personalised spaced-practice

One can categorise items as unknown, not confidently known and confidently known. Indeed, this categorisation can be taken further with degrees of tested and subjectively assessed knowledge. However fine-grained the schema, an adaptive system can deliver spaced-practice items based on a mathematical judgement (algorithms) that decide on the optimal delivery of those items. This optimum delivery schedule is based on what the science tells us and data drawn from learner performance and learner perceptions.

Such systems deliver personalised spaced-practice that is determined not by a preordained sequence but by identifying what the user can actually recall going forward. A useful technique is to gradually drop items that are well known. This selective presentation of items gradually drops items off the conveyer until no items remain. Like a Sat Nav, it delivers the right corrective action depending on where it thinks you are. Sometimes it may deliver in a fairly predictable fashion as you are doing well, at other times it may deliver more items over a longer period if you're showing signs of poor recall or confidence.

Scheduling spaced-practice can be tricky. An 80:20 ratio can be used here to distinguish between the bulk of the 'consolidation practice period' (80% of the time) and its final 'fixing period' (20% of the time). The consolidation period closes gaps, gradually drops items and increases recall. The fixing period simply increases speed of recall.

By distributing workload over time, this method can contribute greatly to reducing worry and cognitive overload in students. Rather than procrastination leading to cramming, we have a balanced workload that consolidates and improves performance smoothly over time. Far from demotivating learners, spaced-practice can motivate by raising self-confidence, meeting expectations and achieving goals.

Adaptive spaced-practice

Adaptive learning, in some forms, especially those that use algorithms, may have an algorithm that checks for competence and builds in spaced practice by presenting content that the it knows the learner found difficult or took longer to learn. This dynamic form of spaced-practice is used, for example, in the CogBooks system (www.cogbooks.com).

This is personalised space-practice, as it presents content on the basis of what it learns about you as a learner, reconfiguring that content in real time to make sure you have an optimal spaced learning experience. This form of spaced-practice is deliberate within a course and has the advantage of being fine-tuned dynamically in response to an individual's performance. It may, in time, be the most sophisticated form of spaced practice available.

Wearables

Lastly, we now have the promise of wearables like Google Glass, which are literally with you as you live, and give you ready access to pull or push spaced-practice at any time. They have the advantage of being able to deliver as audio, image or text.

Similarly with health wearables that deliver alerts for diabetes patients and those suffering from disorders that need reminders of some sort. This technology brings spaced-practice to your eyes, ears and skin. Future devices may even be implanted.

Conclusion

There is a tendency in education and training to see teaching as an 'art form' or 'practice' not helped much by theory, especially psychology. This simply begs the question of what 'practices' are most efficient and productive. However, in this one area, memory theory and spaced-practice, we have a theory, set of clear principles and evidence that lead to clear, best practice, leading to improved performance.

Good learners learn to do this the hard way, by inefficient studying, but eventually adopt their own spaced-practice strategies. We have also shown that these strategies can be taught, recommended and applied, either informally or formally through the use of existing, free technology and more advanced systems.

Spaced-practice is arguably the most powerful, yet most overlooked benefit in learning and true performance. Implemented properly and it is possible to have huge gains in productivity, namely the retention and recall of whatever has been learnt. One could go further and say that without a spaced-practice strategy, there is no learning strategy.

At Learning Pool, our passion is for building low cost, innovative services that help customers deliver real performance improvement.

Hopefully we've injected some fresh thinking about how you can implement spaced practice in your organisation. Encore is our spaced-practice mobile app, allowing you to send bite-sized refresher training to your learners after they take the initial training.

Talk to us about how we can help you get the most out of learning technologies to help improve business performance:

W: learningpool.com
E: hello@learningpool.com
T: 02071019383

Bibliography

Allen, G. A., Mahler, W. A., & Estes, W. K. (1969). Effects of recall tests on long-term retention of paired associates. Journal of Verbal Learning and Verbal Behavior, 8, 463- 470.

Anderson, J R. (1994) Learning and Memory: An Integrated Approach. John Wiley& Sons, NY, NY.

Augé, M. (1995). Non-places: Introduction to an anthropology of supermodernity. London: Verso.

Anderson, R. (1981) Interference: The Relationship Between Response Latency and Response Accuracy. Journal of Experimental Psychology: Human Learning and Memory. 7, 326-343

Barnes, C.A. (1979) Memory deficits associated with senescence: A neurophysiological and behavioral study in the rat. J. Comp. Physiol. 43, 74-104

Bligh, D. A. (2000). What's the use of lectures? San Francisco: Jossey-Bass.

Bjork R.A. (1975) Retrieval as a memory solidifier: An interpretation of negative recency and related phenomena. In RL Solso (Ed.) Information processing and cognition (123-124) Hillsdle, NJ: Erbaum

Bjork R.A. (1988) Retrieval practice and the maintenance of knowledge. In M.M. Gruneberg, P.E. Morris, and R.N. Sykes (Eds) Practical aspects of memory: current research and issues John Wiley& Sons, NY, NY.

Carnine D. (1989) Designing practice activities. J. Learning Disabilities, 22, 603-607

Demspter F.N. (1988) The spacing effect. A case study in the failure to apply the results of psychological research. Am. Psychol. 43, 627-634

Dudai, Y. (1996) Consolidation: fragility on the road to the engram. Neuron 17, 367-370.

Ebbinghaus, H. (1913) Memory: A contribution to experimental psychology (H.A. Ruger & C.E. Bussenues, Trans.). New York: Teachers college, Columbia University. (Originally published 1885).

Ellenbogen J. Scientific American July 2006
Gates A.I. (1917) Recitation as a factor in memorizing. Arch. Phschol. 6, 40.

Hogan, R. M., & Kintsch, W. (1971). Differential effects of study and test trials on long- term recognition and recall. Journal of Verbal Learning and Verbal Behavior, 10, 562- 567.

Keppel G. (1964) Facilitation in short- and long-term retention of paired associates following distributed practice in learning. J. Verbal Learn. and Verbal Behav. 3, 91-111

Kuiper, T.B & Kirker, W. S. (1977). Self-reference and the encoding of personal information. Journal of Personality & Social Psychology, 35(9), 677–688.

Kuo, T. M., & Hirshman, E. (1996). Investigations of the testing effect. American Journal of Psychology, 109, 451-464.

Landauer T.K. and Bjork R.A. (1978) Optimal rehearsal patterns and name learning. In M. Gruneberg, P.E. Morris and R.N. Sykes (Eds). Practical aspects of memory (pp 625-632). London: Academic press.

Moray, N. (1959) Attention in dichotic listening: affective cues and the influence of instructions. Quart. J. Exp. Psychology, 11, 56-60

Morris C.D., Brandsford J.D. and Franks J.J. (1977) Levels of processing versus transfer-appropriate processing. J. Verbal Learning and Verbal Behav. 16, 519-533

Nelson T.O. and Narens L. (1990) Metamemory: a theoretical framework and new findings. In G. Bower (Ed.) The psychology of learning and motivation (Vol. 26) New York: Academic Press.

Nelson T.O., Leonesio R.J. (1988) Allocation of self-paced study time and the "labor-in-vain effect". J Exp Psychol Learn Mem Cogn. 14, 676-86.

Nungester, R. J., & Duchastel, P. C. (1982). Testing versus review: Effects on retention. Journal of Educational Psychology, 74, 18-22.
Syed, M. (2011). Bounce: The myth of talent and the power of practice.

Tulving E. and Madigan S.A. (1970) Memory and verbal learning. In P.H. Mussen and & M.R. Rosenweig (Eds.), Annual review of psychology. Palo Alto, CA

Wickelgren W.A. (1976) Memory storage dynamics. In W.K. Estes (Ed.), Handbook of learning and cognitive process. (Vol. 4) Hillsdale, NJ: Erlbaum

Wittrock, M.C. (1974). Learning as a generative process. Educational Psychologist, 11, 87-95.

Wittrock, M.C. (1990). Generative processes of comprehension. Educational Psychologist, 24, 345-376.

Wittrock, M.C, & Alesandrini, K. (1990). Generation of summaries and analogies and analytic and holistic abilities. American Educational Research Journal, 27, 489-5 http://www.pinterest.com/pin/184366178468962250/02.
Zechmeister, E. B., & Shaughnessy, J. J. (1980). When you know that you know and when you think that you know but you don't. Bulletin of the Psychonomic Society, 15, 41-44.

Video:

Wil Thalheimer
https://www.youtube.com/watch?v=lItgAV6Ly6M

Mark McDaniel
https://www.youtube.com/watch?v=0LvKvZUNqIk

Infographic - Memory Rentention and the Forgetting Curve
http://www.pinterest.com/pin/184366178468962250/